A Cineradiographic Study on the Movement of the soft Palate During Phonation of Speech Sounds

AUTHOR(S):

Hiroto, Ikuichiro; Hirano, Minoru; Umeno, Masayoshi

CITATION:

Hiroto, Ikuichiro ...[et al]. A Cineradiographic Study on the Movement of the soft Palate During Phonation of Speech Sounds. 音声科学研究 1964, 3: 35-46

ISSUE DATE:

1964

URL:

http://hdl.handle.net/2433/52621

STUDIA PHONOLOGIA III (1963)

A Cineradiographic Study on the Movement of the Soft Palate During Phonation of Speech Sounds

Ikuichiro HIROTO, Minoru HIRANO
and Masayoshi UMENO

Much research has been done on the movement of the soft palate during phonation. Most of it, however, has been studies on movement during the phonation of vowels and not on movement during consonant phonation. Furthermore, only an instantaneous phase of the movement was observed in those studies, and so far little observation has been done on the continuous course of the movement of the soft palate. Movements of the vocal tract are usually observed by the following methods: (1) measurement of nasal air pressure, (2) radiographical methods, and (3) electromyographical methods: In the authors case, the movement of the soft palate during phonation of speech sounds was observed using the high voltage cineradiography with electronic image amplifier, analysing the speech sounds recorded simultaneously on a sonagram.

Materials and Methods

The subject: Three healthy males and three healthy females. The subject phonated, lateral projection was performed on the head and neck of the standing subject using the image amplifier; (tube volt. 120 KV, tube electric intensity 5 mA, lens F 2.8, film speed 64 frames/sec., film size 16 mm.).

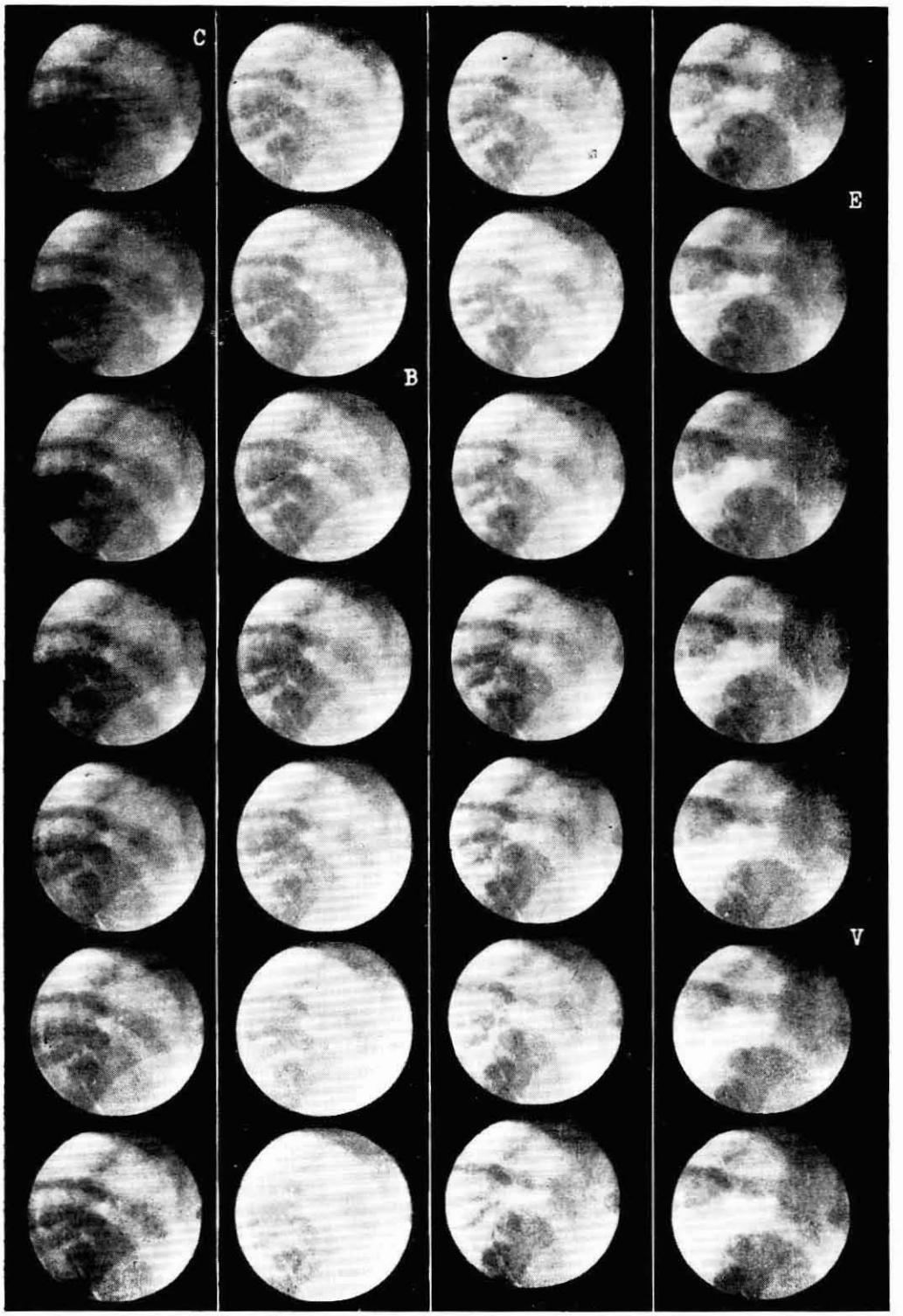
The details of the projection were as follows. When two metal sticks were clicked in front of the face, the subject breathed in and phonated a speech sound. This process was filmed by X-ray, and at the same time, both the subject's phonation and the metal stick click were put into a tape-recorder through a microphone set in front of the subject's mouth.

First the general movement of the soft palate was studied from the movie; then an investigation and analysis of the soft palate movements were made projecting the film frame by frame on white paper, and the movement of the soft palate was analysed using the time of the click sound as the standard point of the movement. The movement of the vocal tract was also observed more closely from the enlarged positive pictures.

On the other hand, the sonagrams of speech sounds were examined and analysed in respect to the time of voice production as compared to the click of metal sticks.

Ikuichiro HIROTO (広戸幾一郎), MinoruHIRANO (平野実) and Masayoshi UMENO (梅野正義): Department of Otolaryngology, Kurume University School of Medicine, Kurume, Japan

Fig. 1. Cineradiogram during phonation of vowel "a".



As the film was taken at a speed of 64 frames/sec., the time from one frame to the next was 1/64 sec. Therefore, if there are "a" frames between the frame where two metal sticks click and the frame where the soft palate finishes its movement of elevation, the time from the moment of the click to the moment of the completion of movement of the soft palate elevation is a/64 sec. In this case, the accidental error of measurement is considered to be 1/64 sec., that is, within 15.6 msec.

As to the sonagram, 318 mm. is equivalent to 2.4 sec. If it is "b" mm. from the point of the click of metal sticks to the point of the voice production, the time from the click to the voice production is accordingly $2.4 \times b/318$ sec.

The instant in which two metal sticks click and which is shown in one of the frames of the film is naturally in accord with the point of the click on the sonagram. So with this point as the standard, the time-relation between the movement of the soft palate shown on the film and the voice production recorded on the sonagram can be compared and examined for each speech sound.

On the sonagram, as the beginning point of the voice production, the point of sound wave in the case of vowel syllables, the point of noise pattern in the case of voiceless consonant syllables, the point of the preceding wave in the case of the voiced consonant syllables, and the point of consonant sound wave in the case of nasal and lateral syllables were respectively adopted. (Fig. 1)

Results

1. The movement of the soft palate was examined from X-ray movie projected figures in reference to the degree of elevation of the soft palate during phonation of speech sounds. (Fig. 2, Fig. 3)

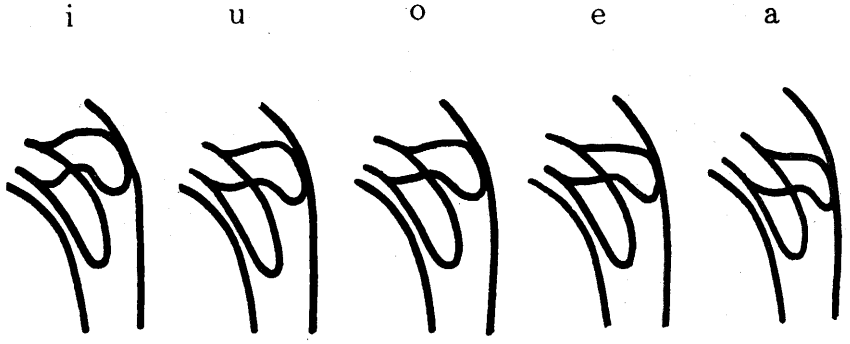


Fig. 2. Movement of the soft palate during phonation of vowels.

2. Comparison of X-ray movies with sonagrams in regard to the time-relation between the motion of the vocal tract and the voice composition was made (Fig. 4) "C" shows the moment of the metal stick click, "B" the moment of the beginning of the soft palate elevation, "E" the moment of the end of elevation, and "V" the mement of the beginning of the voice composition, respectively. The

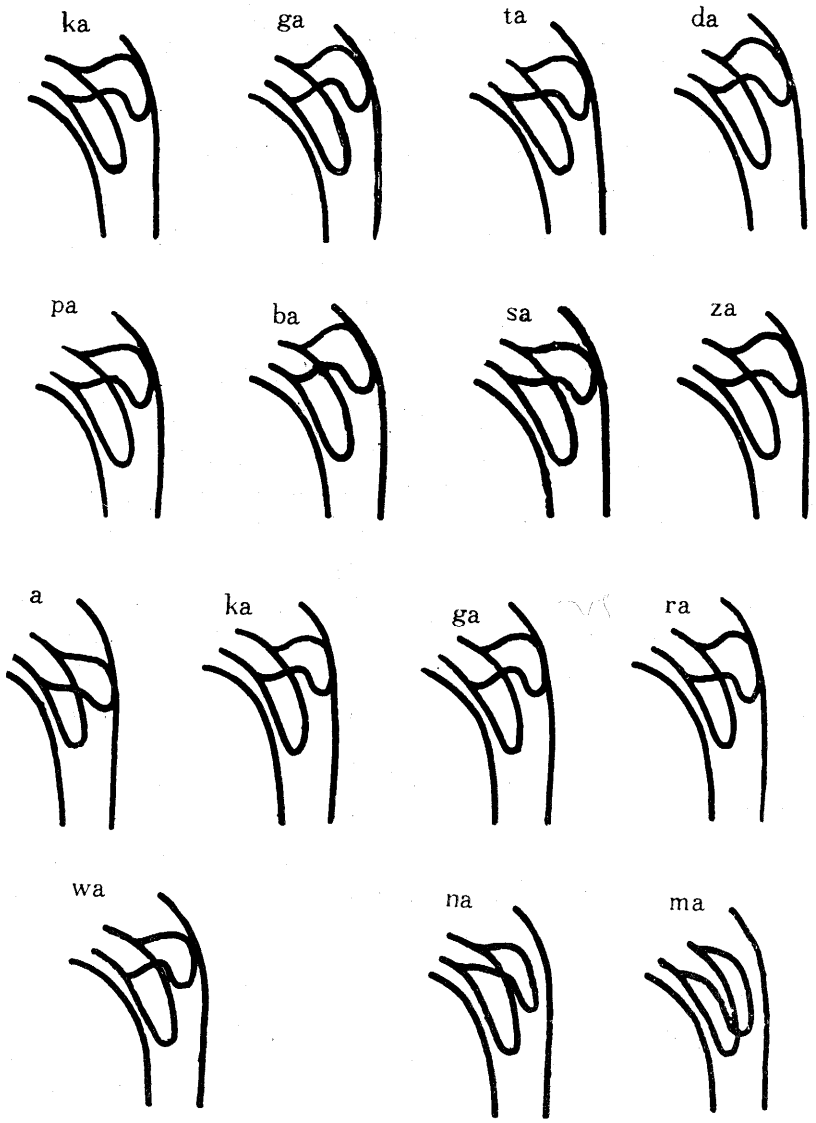


Fig. 3. Movement of the soft palate during phonation of semivowels, nasals, laterals and consonants.

results obtained from the six subjects are shown in Figures 5–8. (Each bunch of six vertical lines is the result of the six subjects for each speech sound.)

In these figures, o-line shows the beginning point of the voice production, the upper end of the vertical line shows the moment of the beginning of the soft palate elevation, and the lower one the moment of the end of the elevation, e.g., in the case of the first subject in Fig. 6 (the phonation of "a"), the elevation of the soft palate begins 300 msec. and ends 100 msec. before phonation. The averages of the six subjects for each speech sound are shown in Tables 1–5.

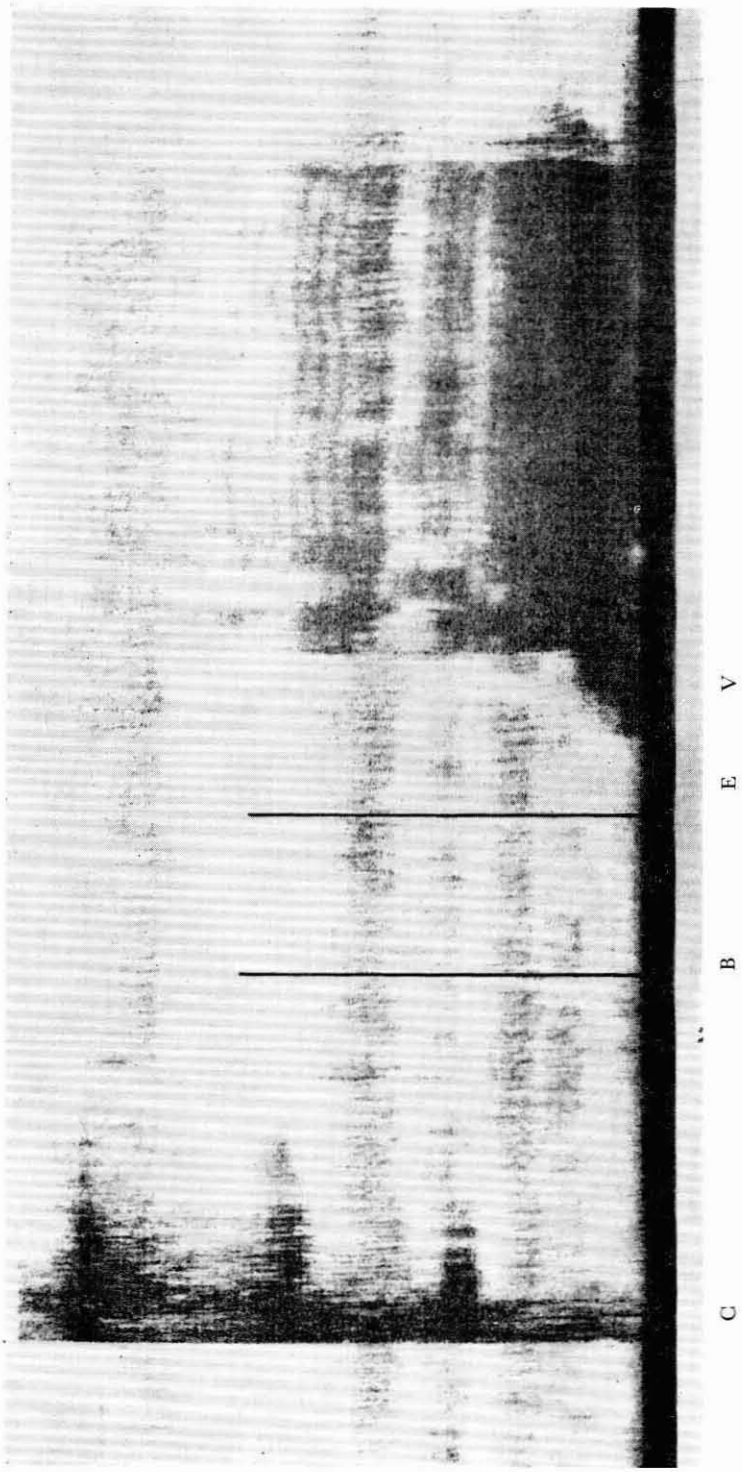


Fig. 4. Sonagram of "ga".

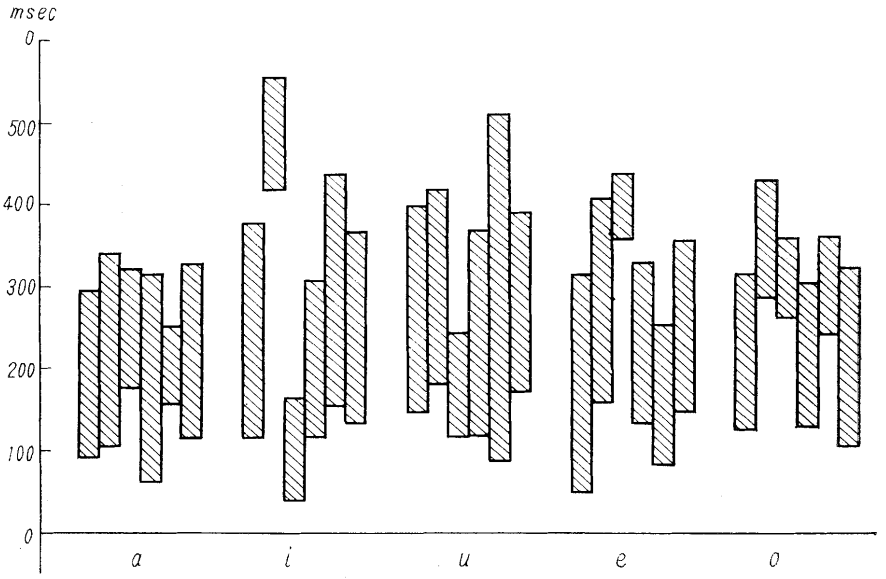


Fig. 5. Time-relation between the movement of soft palate and the phonation of vowels.

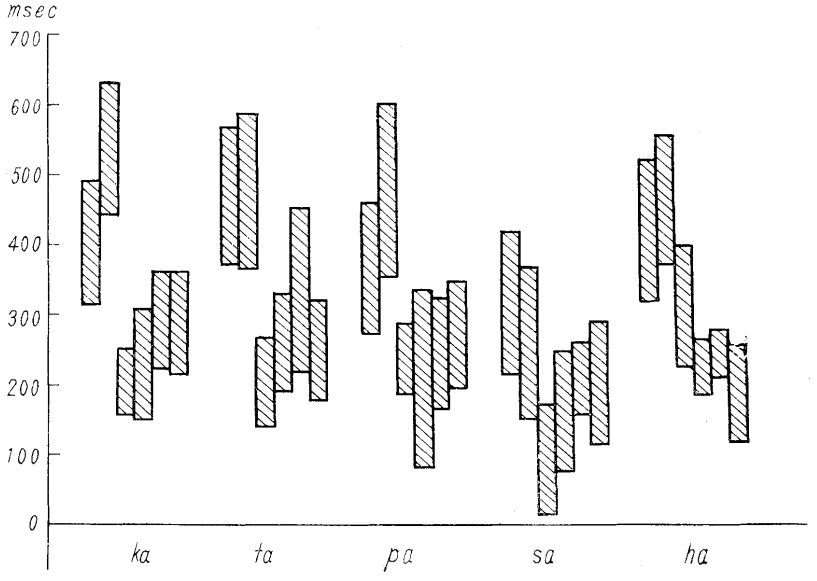


Fig. 6. Time-relation between the movement of soft palate and the phonation of voiceless consonants.

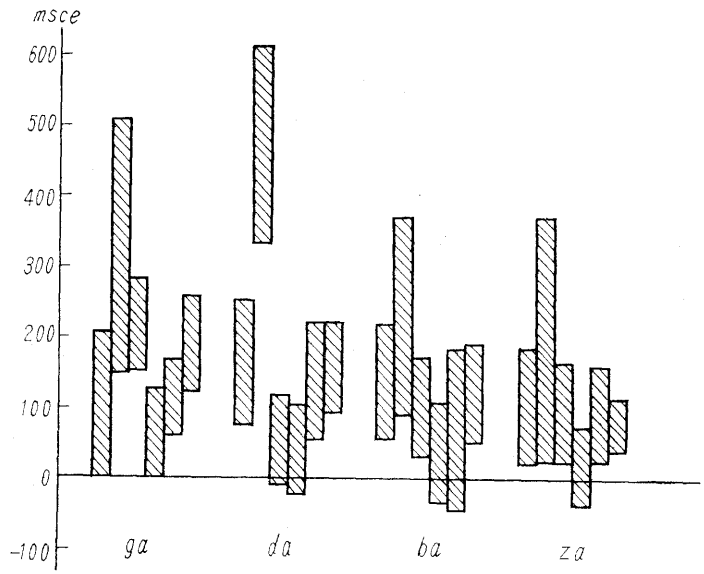


Fig. 7. Time-relation between the movement of soft palate and the phonation of voiced consonants.

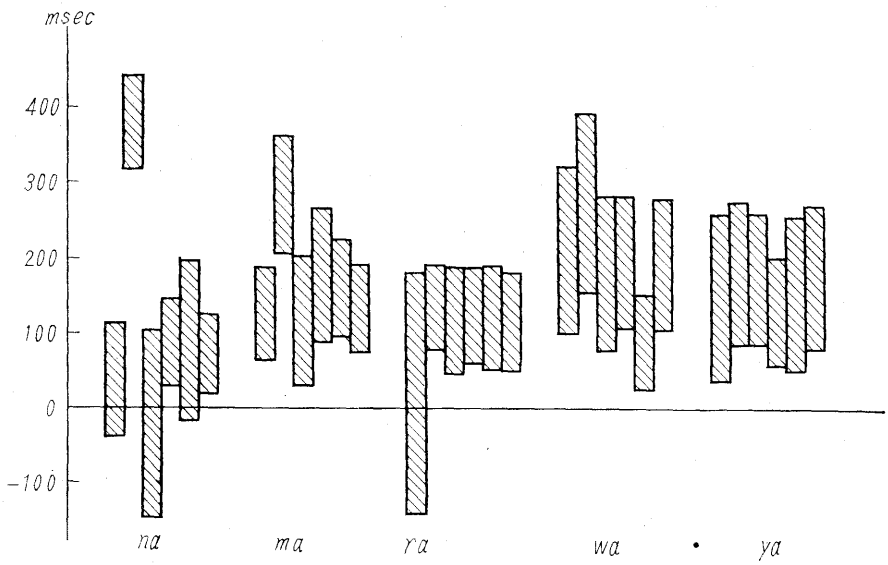


Fig. 8. Time-relation between the movement of soft palate and the phonation of nasals, laterals, and semivowels.

Table 1
vowels (msec.)

	B–E	E–V	B–V
u	250	135	385
o	138	189	345
a	189	118	307
e	202	144	346
i	204	161	365
average	196.4	149.4	349.8

Table 2
voiceless consonants (msec.)

	B–E	E–V	B–V
ka	150	251	401
sa	172	120	292
ta	175	244	419
pa	183	208	391
ha	141	237	378
average	164.2	212.0	369.2

Table 3
voiced consonants (msec.)

	B–E	E–V	B–V
ga	176	82	258
za	161	16	177
da	167	87	254
ba	167	39	206
average	167.8	56.0	223.8

Table 4
nasals (msec.)

	B–E	E–V	B–V
na	169	18	187
ma	148	93	241
average	158.5	55.5	214.0

Table 5
lateral and semivowels (msec.)

	B–E	E–V	B–V
ra	161	24	185
wa	186	95	281
ya	185	66	251

Summary

As to the closure of epipharynx, various results have been reported. J. Czermak obtained the result that the closure was marked with the phonation of vowels "i", "u", "o" but not with "e" and "a". According to O. Joachim, the closure was incomplete with the phonation of "e", "o" and "a", but the closure was complete with "i", "u" and consonant sounds except "m" and "n". M. Scheier reported that the closure was marked with the phonation of vowel sounds, but not with "m", "n" and "ng". In H. Gutzmann's report, the closure was marked with vowels and consonant sounds except "m", "n" and "ng". According to the results of the authors' experiments the closure of epipharynx was marked prior to the beginning of phonation of speech sounds except "na" and "ma". The oder of degree of elevation of the soft palate, that is, the degree of the closure of the epipharynx (Fig. 2) was as follows: "i" > "u" > "e" > "o" > "a". In the case of the phonation of voiceless consonants, the difference in degree between each sound was very slight; there was, however, the tendency for the degree to be higher in the phonation of explosive sounds, "ka", "ta" and "pa", as compared with fricative sounds, "ha" "sa". (Fig. 3) The epipharynx did not close in the case of the phonation of nasals. (Fig. 3) Voiced consonants > Voiceless consonants > Vowels > Nasals is the order observed according to the degree of epipharynx closure.

To observe the movement of the soft palate during phonation of speech sounds, various methods have been tried. Czermak (1859) put a probe through the nasal cavity and fixed it on the back of the soft palate, and then the movement of the soft palate during phonation and deglutition was observed mechanographically. By Oakleg and Coles (1871), the movement of the soft palate and the tongue was observed putting gum arabic and flour on the lower face of the soft palate. O. Joachim (1889) observed, on a patient with a defective outer nose, the movement of the soft palate from the nasal cavity during the vowel phonation. L. D. Robotnaff (1925) inserted a balloon in the epipharynx and observed the mechanism of the soft palate. By M. Scheier (1896) a radiographical report was first presented. E. Barth (1907) studied radiographically the position of the uvula during the phonation of five vowels using a metal chain. E. Grunmach (1907), M. Handek and E. Fröschel (1911) observed the movements of the tongue, the mouth and lips, and the soft palate during phonation of speech sounds using Bismuth paste. As to X-ray movies, H. Gutzmann (1938) used a 48-frame/sec. X-ray movie made by Janker-Bonn in his work. G. Guillen et al. (1957) observed the movement of the tongue and the soft palate during phonation from an X-ray movie.

As to the use of an image amplifier, B. Schlosshauer and G. Möckel (1955) and Hiroto and Sawada (1957) used it in making studies the mechanism of phonation of esophageal speech, and Hiroto and Shimazu (1959) on the movement of the vocal cord. In the authors' case, the movement of the soft palate was ob-

served using the high voltage cineradiography (120 KVP) with an image amplifier, and comparing it with the sonagraphically analysed speech sounds.

There were remarkable individual differences concerning the time of the soft palate movement. On the other hand, according to Hiroto and Shimizu's report the individual difference was little in reference to the time-relation between the movement of vocal cord and the phonation of speech sounds. The individual differences of the soft palate movement might be presumed to be due to (1) the differences in the attack of voice and (2) the differences of each subject's consciousness about phonation. Especially in articulation mechanism the subject's birthplace and place of growth, that is, local accents, have a significant influence. This is one of the most important factors in individual differences concerning soft palate movement.

The closure of epipharynx is completed before the beginning of phonation of speech sounds except for the voiced consonants "da", "za", "ba", the nasal "na", and the lateral "ra". In the case of these sounds the closing movement of the epipharynx is not finished before voice production, that is, these sounds are articulated during elevation of the soft palate.

The time from the beginning of the soft palate movement to the voice production, in the case of vowels, is an average of 350 msec., and the vowels in order of time-length are: "u" > "i" > "e", "o" > "a". The time of the soft palate movement is an average of 196 msec., and "u" > "e", "i", "a" > "o" is the oder according to the time-length. These results agree with the fact that the degree of elevation of the soft palate is higher during the phonation of "i" and "u" than during that of "o", "e" and "a".

The time from the beginning of the soft palate movement to the voice production of voiceless consonants is an average of 369 msec., and the consonants in order of time-length are: "ta" > "ka", "pa", "ha" > "sa". The time of the movement of the soft palate is an average of 164 msec., and it is longer during the phonation of "pa", "ta", "sa" than during that of "ka" and "ha".

In the case of voiced consonants, the time from the beginning of the soft palate movement to voice production is an average of 224 msec., and the oder according to the time-length is: "ga", "da" > "ba" > "za". The time of the soft palate movement is an average of 168 msec., and the difference in time is little between each sound.

In the case of nasals, the time from the beginning of the soft palate movement to voice production is an average of 214 msec., and it is longer during the phonation of "ma" than "na". The time of the soft palate movement is an average of 159 msec., and the difference in time between "ma" and "na" is not appreciable.

To compare each group of speech sounds in reference to the movement of the soft palate; voiceless consonants, vowels > voiced consonants, nasals is the order according to the time from the elevation of the soft palate to voice production,

and vowels>voiceless consonants, voiced consonants, nasals is the order according to the time from the beginning of elevation of the soft palate to the completion of the movement. Voiceless consonants>vowels>voiced consonants, nasals is the order according to the time-length from the completion of elevation of the soft palate to the voice production.

To compare "ka" with "ga", "ta" with "da", "pa" with "ba", and "sa" with "za", that is, to compare a voiceless consonant with a voiced one located in the same articulation zone, both the time from the beginning of elevation of the soft palate to the voice production and the time from the completion of elevation of the soft palate to the voice production are longer in the case of voiceless consonants than in voiced consonants, and it is shown that either the beginning or the completion of elevation of the soft palate ends earlier with voiceless consonants than with voiced consonants.

Both the time from the beginning of elevation of the soft palate to voice production and the time from the completion of the elevation to voice production are longer in the case of plosive sounds as compared with fricative sounds, regardless of voiceless or voiced syllables. According to Hiroto and Shimizu's report on the movement of the vocal cord, the time from the beginning of closure of the glottis to the phonation of voiceless syllables is longer in the case of plosive sounds than fricative sounds. These two results indicate that there is a correlation between the mechanism of voice production and the mechanism of articulation.

Conclusion

The movements of the soft palate during phonation of speech sounds were observed using the high voltage cineradiography with an electronic image amplifier and compared with analysed speech sounds on the sonagram.

1. In most cases the closure of the epipharynx finished before the beginning of phonation of speech sounds.

2. There were remarkable individual differences in the movement of the soft palate during phonation of speech sounds.

3. The movement of the soft palate began earlier in the case of vowels and voiceless consonants, as compared with voiced consonants and nasals.

4. To compare a voiceless consonant and a voiced consonant located in the same articulation zone, the movement of the soft palate began earlier in the case of voiceless consonants than in the case of voiced consonants.

5. The movement of the soft palate began earlier in the case of plosive sounds as compared with fricative sounds, regardless of voiceless or voiced syllables.

6. The order according to the degree of elevation of the soft palate during phonation of the five vowels was: "i">"u">"o">"e">"a".

7. To compare a voiceless and a voiced consonant in the same articulation zone, the position of the soft palate during phonation was higher in the case of

voiceless consonants as compared with voiced consonants.

8. The complete closure of the epipharynx was marked with vowels and consonant sounds, but it was incomplete with nasals.

LITERATURES

1. Czermak : Über das Verhalten des weichen Gaumens bei Hervorbringen der reinen Vokale Gesammte Schriften. 1 : 423, 1875.
2. Oakley Coles, T. : Transsection of the Odontological Society of Great Britain. 4 : 110, 1871.
3. Oertel, M.J. : Das Laryngostroboskop und die Laryngostroboskopuntersuchung. Arch. f. Laryng. 3 : 1, 1895.
4. Joachim, O. : Beitraege zur Physiologie des Gaumensegels. Zeits. f. Ohrenh. 19 : 50, 1889.
5. Rabotnoff, L.D. : Ueber die Funktion des weichen Gaumens beim Singen. Zeits. f. Ohrenh. 11 : 546, 1925.
6. Scheier, M. : Die Verwertung der Roentgenstrahren fuer die Physiologie der Sprache und Stimme. Archiv. f. Laryng. 7 : 116, 1898.
7. Scheier, M. : Die Bedeutung des Roentgenverfahrens fuer die Physiologie der Sprache und Stimme. Archiv. f. Laryng. 22 : 175, 1909.
8. Barth, E. : Roentgenographische Beitraege zur Stimmphysiologie. Archiv. f. Laryng. 19 : 396, 1907.
9. Grunmach, E. : Roentgentechnik zur Untersuchung der Mund, Schlund und Nasenhoehle bei der Phonation. Archiv. f. Laryng. 19 : 405, 1907.
10. Handek, M., Froescheles, E. : Roentgenaufnahmen der Form des Ansatzrohres bei den Sprachlauten. Archiv. f. Laryng. 24 : 319, 1911.
11. Brunner and Fruehwald : Untersuchungen ueber die Vokalbildungen bei taubstummen Kinder. Zeits. f. Ohrheilk. 6 : 156, 1923.
12. Dylewski, B. : Untersuchugen ueber die Rolle des weichen Gaumens beim Sprachen und Singen. Monats. f. Ohrheilk. 63 : 538, 1929.
13. Gutzmann, H. : Roentgenaufnahmen von Zunge und Gaumensgel bei Vokalen und Dauerkonsonanten. Forts. d. Roent. 41 : 392, 1930.
14. Robert, C. : Physiologie d'une Voix de Soprano. Ztbl. f. H. N. O. 31 : 479, 1938.
15. Greineder, K. : Die Schichtuntersuchung der Kehlkopf. Ztbl. f. H. N. O. 31 : 658, 1938.
16. Scala, D. A. and Sacco, M. : Studium der Phonation beim Normalen und beim Pathologischen vormittels der Stratigraphie. Ztbl. f. H. N. O. 55 : 151, 1956.
17. Gutzmann, H. : Roentgenfilm des Sprachvorganges. Zeits. f. Ohrheilk. 44 : 447, 1938.
18. Janker : Appratus und Technik der Roentgenkinematographie zur Darstellung der Herzbinnenraeum. Forts. Roentgenpraxis. 72 : 513, 1950.
19. Schlosshauer, B. and Moeckel, G. : Roentgenkinematographische Darstellung der Pseudosprache nach Laryngektomie. Ztbl. f. N. N. O. 31 : 658, 1938.